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PREDICTED SEAFLOOR SUBSIDENCE PROFILE DATA USING A 'MODIFIED' NCB SUBSIDENCE ENGINEERS HANDBOOK METHOD FOR THE PRINCE, LINGAN AND NO. 26 MINES, SYDNEY COALFIELD, N.S.

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by

T.R.C. Aston*

SUMMARY

The report summarises the predicted subsidence profile parameters of maximum vertical subsidence, tensile and compressive strain at seabed, using a 'modified' NCB Subsidence Engineers Handbook method, for the single seam workings at the Prince, Lingan and No. 26 Mines, Sydney Coalfield, Nova Scotia. The modification involved changing the tensile strain prediction factor 'k' from a variable (0.55 to 0.85) to a constant (0.80) for different panel width/depth ratios.

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PRÉDICTION DE DONNÉES RELATIVES AU PROFIL DE SUBSIDENCE DU FOND MARIN AUX MINES PRINCE, LINGAN, ET N° 26, À LA HOUILLÈRE DE SYDNEY, N.-É., AU MOYEN D'UNE MÉTHODE 'MODIFIÉE' PUBLIÉE PAR LA NCB DANS LE GUIDE DE L'INGÉNIEUR

par

T.R.C. Aston*

RÉSUMÉ

Le présent rapport fait état des paramètres du profil de subsidence verticale maximale, de l'effort de traction et de la déformation du fond marin par compression pendant l'exploitation d'une seule couche de houille aux mines Prince, Lingan et N° 26, à la houillère de Sydney en Nouvelle-Écosse. À ces fins, nous avons utilisé une méthode modifiée, tirée du Guide de l'ingénieur et portant sur la subsidence. Les modifications apportées à la méthode consistaient dans le changement du facteur 'k' d'une variable (0,55 à 0,85) qui sert à prédire l'effort de traction à une constante (0,80) pour les différents rapports largeur/profondeur des panneaux.

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INTRODUCTION

Underground mining operations in the Sydney Coalfield are undertaken by a federal Crown corporation - the Cape Breton Development Corporation (CBDC). Three mines are currently operating: Lingan (dual entry advance longwall) and Phalen and Prince (dual entry retreat longwall). A fourth mine, No. 26 Mine, operated until April 1984 when a fire in the main intake roadways resulted in its closure. In addition to the four mines already mentioned, one new mine has also been partially developed: Donkin-Morien (on hold, May 1987).

At the Lingan and Prince Mines, single seam mining over the next five years will work 1.5 to 2.5 m seams with face lengths between 100 and 250 m at depths between 200 and 700 m below seabed. The new mine proposals, the Donkin-Morien and Phalen, call for longwall mining at depths up to 600 m with extracted seam heights up to 3.5 m and face lengths up to 250 m. Second and third seam working is anticipated at Donkin-Morien, while the Phalen Mine will undermine existing Lingan workings.

The Cape Breton Coal Research Laboratory (CBCRL) has recently developed a computer program (1,2) which undertakes the calculation of subsidence profiles using the methods given in the National Coal Board Subsidence Engineers Handbook (NCB SEH) (3). Predicted seafloor subsidence values and maximum tensile and compressive strains, calculated using the NCB SEH method, for single seam workings of the Prince, Lingan and No. 26 Mines, Sydney Coalfield are presented elsewhere (4).

At the request of CBDC, the tensile strain prediction factor 'k' was altered within the original NCB SEH program. This report summarises the predicted subsidence profile parameters of maximum vertical subsidence, maximum tensile and compressive strain at seabed, calculated using the NCB SEH method, but with a modified tensile strain 'k' factor value, for the single seam workings of the Prince, Lingan and No. 26 Mines, Sydney Coalfield, N.S.

GEOLOGY OF THE SYDNEY COALFIELD

Geologically, the Sydney Coalfield is Pennsylvanian (Westphalian) in age and lies within some 2,200 m of strata known as the Pictou group. The

coalfield outcrop lies inland of the coastline and dips seaward at between 4 and 10 degrees, although localised variations in dip occur between 2 and 40 degrees (5). Structurally, the area consists of a shallow north-easterly plunging fold system with a general orientation of north-west to south-east. Four synclinal structures also exist, in addition to a variety of minor faults and folds which affect the submarine portion of the coalfield. The northern and southern boundaries of the coalfield are delineated by major fault zones with throws in excess of 600 m.

A consequence of the north-easterly dip of the coalfield is that most of the coal reserves lie within the submarine portion of the coalfield. At present, mining extends some 5 km from the shoreline without deterioration of the coal seam quality or thickness.

Lithologically, the strata consists of interbedded sequences of sandstone, siltstone, mudstone and coal seams, typical of coal measures strata. Some thin beds of limestone have also been recorded.

A more detailed description of the geology, stratigraphy and structure of the Sydney Coalfield can be found elsewhere (5).

SUBSIDENCE CALCULATION

All subsidence calculations for this report were undertaken using the 'SUB#4' computer program (1,2) with a modified tensile strain 'k' factor. The program is written in BASIC A Version 3.10 for use on an IBM-PC/AT microcomputer and undertakes the calculation and plotting of longwall subsidence profiles using the methods given in the NCB Subsidence Engineers Handbook (3).

PROGRAM MODIFICATION

The universally accepted equation for deriving the maximum tensile strain of a subsidence profile (3,6) is:

$$Em = k\frac{Sm}{D} \qquad \text{Eq 1}$$

where, Em - Maximum tensile strain
k - Mining/geological coefficient varying between 0.5 and 1.0
Sm - Maximum subsidence
D - Depth of working

In the NCB SEH prediction method ('SUB#4' program), the value of 'k' varies between 0.55 (width/depth ratio of 0.20) and 0.65 (width/depth ratio of 1.4). The value 'k' reaches a maximum of 0.85 at a width/depth ratio of 0.46, (3).

In the modified version of 'SUB#4', requested by CBDC, the value of 'k' was altered to equal 0.80 for all width/depth ratios, Table 1.

PROGRAM INPUT

To obtain the necessary data for input to the 'modified SUB#4' program, 1:400 scale plans of the Prince, Lingan and No. 26 mines were examined and the following information tabulated for each of the longwall panels:

Colliery and Seam Name
Panel Identification Number
Panel Width (metres)
Seam Thickness (metres)
Panel Length (metres)
Depth of Cover - mean main and tailgate elevations (metres)
Panel Gradient - across the panel (1 in x)

OUTPUT INTERPRETATION

The NCB Subsidence Engineers Handbook is often viewed as a definitive work on subsidence prediction. However, this can be an erroneous assumption, since it was empirically derived from a data base collected in a variety of U.K. coalfields. Problems occur when it is used in coalfields which were either not included or only poorly represented in the original data base. Similarly, when using empirical methods, it is difficult to quantify the effects of individual parameters such as geology or the presence

Width/Depth Ratio	NCB SEH 'k' value	CBDC 'Modified' 'k' value
0.20	0.55	0.80
0.30	0.70	0.80
0.40	0.80	0.80
0.50	0.80	0.80
0.60	0.80	0.80
0.70	0.70	0.80
0.80	0.65	0.80
0.90	0.65	0.80
1.00	0.65	0.80
1.10	0.65	0.80
1.20	0.65	0.80
1.30	0.65	0.80
1.40	0.65	0.80

Table 1 - NCB SEH and CBDC 'modified' 'k' values for prediction of maximum tensile strain

of existing workings in adjacent seams on the eventual magnitude of the subsidence profile. Caution must therefore be used when applying the NCB SEH to coalfields in countries other than the U.K., even when the conditions to which it is applied are comparable to the coalfields from which the original case histories were collected.

If the Sydney Coalfield is assumed to be similar to the U.K. coalfields, various assumptions and limiting criteria recognised and considerable caution exercised, the 'SUB#4' and modified 'SUB#4' programs can be used to obtain a 'good first order approximation' of the actual subsidence profiles.

PRINCE MINE

At Prince Mine, mining is restricted to single horizon working in the Hub Seam. The workings consist of single entry retreat longwalls with inseam gateroads. At present, ten panels have been worked with the workings extending up to 4.5 km offshore, Figure 1.

Initially, because of the relatively shallow cover between the Hub Seam and seabed, 160 m, a panel and pillar layout was used with 60 m wide panels. However, as the amount of cover increased, the panel width was increased to about 100 m. The mine produces approximately 1 million tonnes of coal per year.

MINING PARAMETERS

Currently ten panels are or have been mined, six on the east side and four on the west side. Mining parameters for the individual panels are given in Tables 2 and 3, but can be summarized as follows:

Parameter	East Side	West Side
Panel Width (m)	61-114	60-105
Mean Extracted Seam Height (m)	1.93-2.09	2.03-2.12
Depth of Working (m)	160-193	160-171
Panel Length (m)	365-1902	622-1272
Mean Seam Gradient (1 in x)	17-22	15-29
Mean Pillar Width (m)	60	55-97

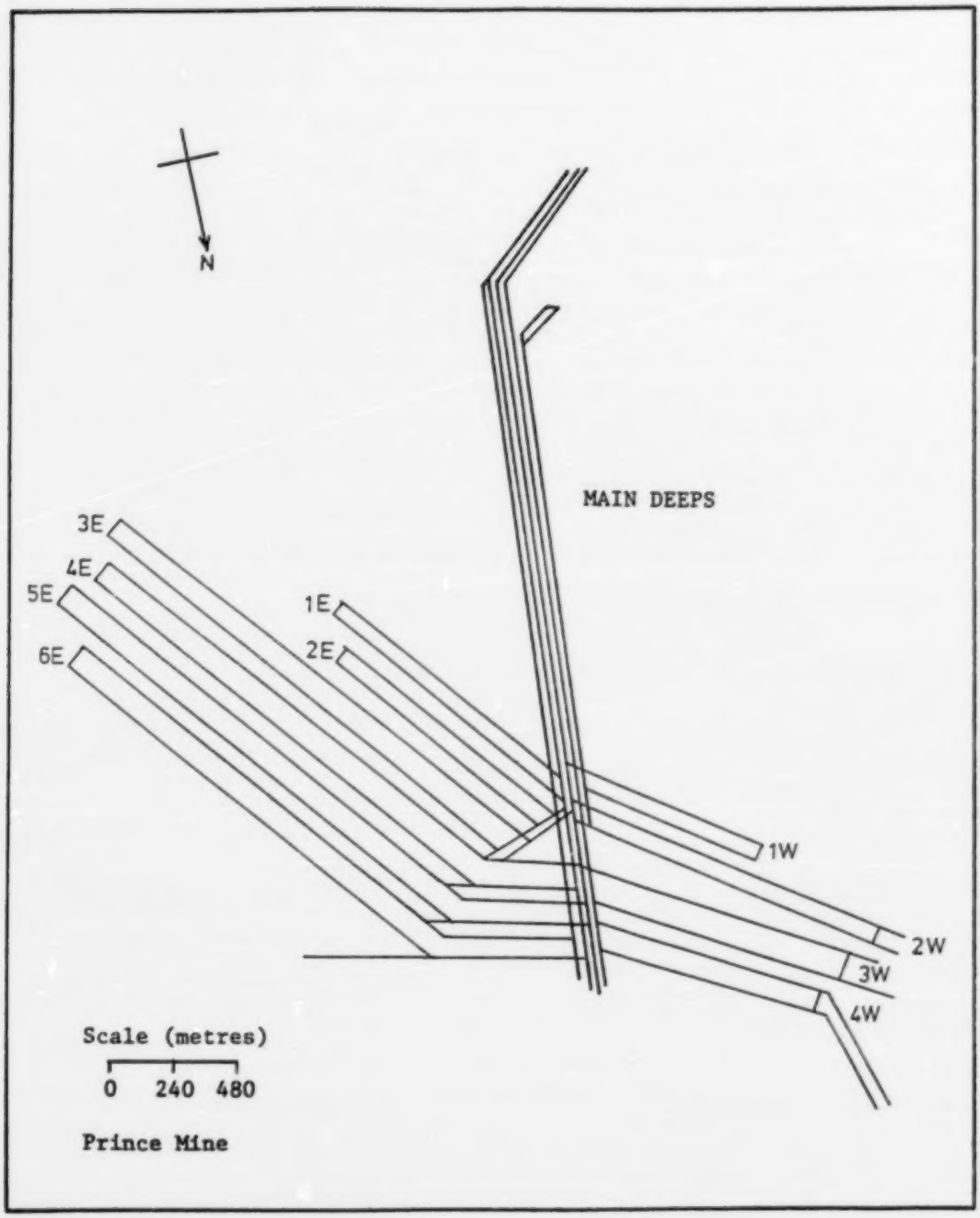

Figure 1 - Prince Mine

Level (Panel)	Face Width (m)	Panel Length (m)	Extracted Seam Ht. (m)			Depth of Cover (m)		
			Max	Min	Mean	Max	Min	Mean
1 East	60.9	908	2.06	1.85	1.93	161.2	158.8	160.1
2 East	67.0	920	2.06	1.90	2.01	167.6	164.0	165.7
3 East	89.9	1902	2.36	1.83	2.11	177.1	166.7	170.8
4 East	97.5	1762	2.13	2.01	2.09	178.7	165.1	171.5
5 East(1)	106.6	1722	2.08	1.96	2.02	196.0	177.1	185.2
5 East(2)	106.6	365	1.98	1.98	1.98	196.0	189.3	192.5
6 East	114.3	1611	2.06	1.91	2.00	202.3	186.0	192.7
1 West	59.4	622	2.03	2.03	2.03	160.1	158.5	159.3
2 West	67.0	1105	2.13	2.03	2.07	168.3	156.4	162.3
3 West	105.1	903	2.11	1.98	2.05	175.5	164.6	171.2
4 West	97.5	1272	2.18	2.06	2.12	175.5	165.4	168.2

Table 2 - Mining Parameters - Prince Mine

Level (Panel)	Gradient Across Panel (1 in x)		
	Max	Min	Mean
1 East	19.2	23.0	20.8
2 East	17.1	26.2	20.6
3 East	16.0	25.1	21.6
4 East	17.8	22.8	19.3
5 East(1)	11.2	21.8	17.0
5 East(2)	11.6	23.3	17.5
6 East	15.6	20.8	18.5
1 West	15.0	15.4	15.3
2 West	17.6	41.9	29.7
3 West	15.6	21.5	19.0
4 West	21.3	35.6	26.5

Table 3 - Seam Gradient - Prince Mine

SUBSIDENCE PARAMETERS

Predicted maximum subsidence, compressive and tensile strain values along with the corrected tensile strain values for the mean seam gradient, using the modified 'SUB#4' program, are given in Table 4. It should be noted that since the mean seam gradient for each panel is less then 1 in 10, the corrected tensile strain values are the same as those values predicted for a flat seam.

Maximum subsidence over the 60 m panels (1 and 2 East and 1 and 2 West) varies between 0.39 and 0.56 m with tensile strain values of between 1.9 and 2.7 mm/m. Once the face width was increased to 100 m, the maximum subsidence values increase to between 0.90 and 1.06 m with tensile strain values of between 3.7 and 5.0 mm/m.

LINGAN MINE

At Lingan Mine, mining is restricted to single horizon workings in the Habour Seam. The workings consist of single entry advancing longwalls, laid out on the panel and pillar system, which extend up to 5.5 km offshore, Figure 2.

The mine has a designed production level of 1.4 million tonnes per year.

MINING PARAMETERS

Currently, fifteen panels are or have been mined, nine on the east side and six on the west side. In early 1986, a sixteenth panel, 10 East commenced production. Mining parameters for the individual panels (except 10 East) are given in Tables 5 and 6, but can be summarized as follows:

Parameter	East Side	West Side
Panel Width (m)	169-203	172-216
Mean Extracted Seam Height (m)	1.90-2.11	1.75-1.92
Depth of Working (m)	272-550	391-552
Panel Length (m)	1600-2570	955-1355*
Mean Seam Gradient (1 in x)	5 to 8	7 to 8
Mean Pillar Width (m)	57-86	38-79

Panel	Max Sub (m)	Max Strain (mm/m)		Gradient (1:x)	Corrected Tensile for Gradient (mm/m)	
		Tens	Comp		Rise	Dip
1 East	0.39	1.93	4.10	20.8	1.93	1.93
2 East	0.52	2.52	5.20	20.6	2.52	2.52
3 East	0.95	4.44	6.67	21.6	4.44	4.44
4 East	1.04	4.87	6.70	19.3	4.87	4.87
5 East(1)	0.91	3.93	5.40	17.0	3.93	3.93
5 East(2)	0.89	3.70	5.32	17.5	3.70	3.70
6 East	0.90	3.74	4.90	18.5	3.74	3.74
1 West	0.41	2.04	4.59	15.3	2.04	2.04
2 West	0.56	2.75	5.68	29.7	2.75	2.75
3 West	1.03	4.49	5.98	19.0	4.49	4.49
4 West	1.06	5.04	6.93	26.5	5.04	5.04

Table 4 - Subsidence Data - Prince Mine (Modified 'SUB#4' Program)

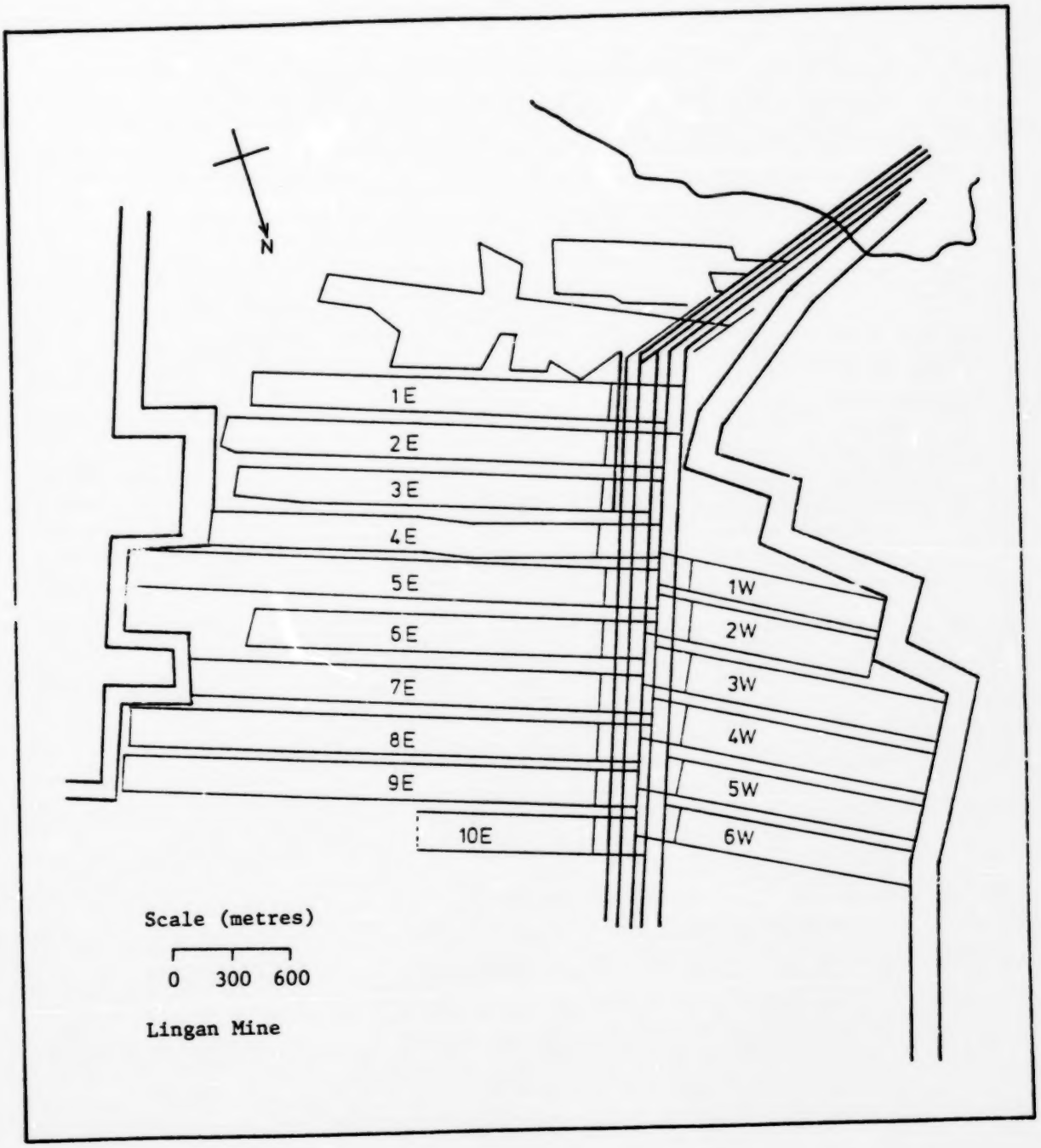

Figure 2 - Lingan Mine

Level (Panel)	Face Width (m)	Panel Length (m)	Extracted Seam Ht. (m)			Depth of Cover (m)		
			Max	Min	Mean	Max	Min	Mean
1 East	178.3	1943	2.08	1.52	1.90	281.2	262.8	272.5
2 East	173.7	2077	2.21	1.88	2.06	321.7	312.2	318.6
3 East	169.2	2003	2.08	1.80	2.00	363.2	355.0	358.3
4 East	181.4	2117	2.03	1.80	1.96	404.0	389.2	398.0
5 East	201.2	2570	2.31	1.98	2.11	442.4	415.7	429.6
6 East	202.7	2179	2.13	1.93	2.03	472.6	449.6	463.1
7 East	199.6	2207	2.13	1.93	2.03	509.9	478.9	494.2
8 East	198.1	2557	2.08	1.83	2.00	561.0	508.1	532.7
9 East	201.1	1597	2.03	1.98	1.99	561.0	538.3	550.3
1 West	172.2	1057	2.08	1.80	1.92	397.4	386.5	391.5
2 West	210.3	955	1.83	1.63	1.75	425.2	415.1	421.1
3 West	207.3	1250	1.98	1.78	1.83	459.0	450.7	455.2
4 West	213.3	1325	2.03	1.75	1.87	490.1	484.5	486.8
5 West	210.3	1280	1.96	1.73	1.84	523.7	517.3	519.0
6 West	216.4	541	1.75	1.75	1.75	554.3	550.0	552.0

Table 5 - Mining Parameters - Lingan Mine

Level (Panel)	Gradient Across Panel (1 in x)		
	Max	Min	Mean
1 East	4.6	5.6	5.0
2 East	5.1	6.2	5.6
3 East	5.5	6.5	6.1
4 East	6.4	7.9	7.1
5 East	5.7	7.7	6.9
6 East	7.2	8.8	7.8
7 East	6.7	9.0	8.0
8 East	6.6	9.0	7.9
9 East	7.7	9.1	8.3
1 West	7.8	8.8	8.4
2 West	8.6	8.9	8.8
3 West	8.0	8.5	8.3
4 West	7.3	8.5	8.0
5 West	6.5	8.7	7.4
6 West	7.2	7.4	7.3

Table 6 - Seam Gradient - Lingan Mine

*At the time of writing, the 6 West panel had only advanced a distance of 541 m, although the projected final length is 1250 m.

As the workings extend further offshore, the depth of cover between the Harbour Seam and seabed increases and the gradient of the seam decreases from about 1 in 5 for the 1 East panel to about 1 in 8 for the 5 to 9 East and 1 to 6 West panels.

SUBSIDENCE PARAMETERS

Predicted maximum subsidence, compressive and tensile strain values along with the corrected tensile strain values for the mean seam gradient are given in Table 7.

Maximum subsidence decreases from 1.25 m (1 East) to 0.58 m (9 East) and from 0.79 m (1 West) to 0.58 m (6 West) with the increasing depth of cover above the workings. Corrected tensile strain values, on the dipside, vary between 5.00 mm/m and 0.96 mm/m (1 to 9 East) and 1.77 mm/m to 0.99 mm/m (1 to 6 West).

NO. 26 MINE

No. 26 Mine operated until April 1984 when a fire in the main intake roadways resulted in its closure. The workings, in its later life, consisted of single entry advancing longwalls laid out on the pillar and panel system, Figure 3. The workings extended up to 8.5 km offshore and the mine had a production capacity of 750,000 tonnes per year.

MINING PARAMETERS

In total, 31 panels were worked at No. 26 and these can be divided into four main sections: 3 to 14 North (North Side), 3 to 13 South (South

Panel	Max Sub (m)	Max Strain (mm/m)		Gradient (1:x)	Corrected Tensile for Gradient (mm/m)	
		Tens	Comp		Rise	Dip
1 East	1.25	3.67	4.13	5.0	2.35	5.00
2 East	1.07	2.69	3.86	5.6	1.91	3.47
3 East	0.90	2.01	3.65	6.1	1.51	2.51
4 East	0.82	1.76	3.10	7.1	1.44	2.07
5 East	0.89	1.65	2.99	6.9	1.32	1.98
6 East	0.77	1.33	2.67	7.8	1.12	1.55
7 East	0.73	1.18	2.44	8.0	1.01	1.36
8 East	0.62	0.93	2.09	7.9	0.79	1.07
9 East	0.58	0.84	1.89	8.3	0.72	0.96
1 West	0.77	1.57	3.13	8.4	1.36	1.77
2 West	0.79	1.50	2.62	8.8	1.32	1.68
3 West	0.73	1.37	2.41	8.3	1.18	1.56
4 West	0.71	1.17	2.33	8.0	0.99	1.34
5 West	0.63	0.96	1.99	7.4	0.80	1.13
6 West incomplete	0.58	0.84	1.78	7.3	0.69	0.99

Table 7 - Subsidence Data - Lingan Mine (Modified 'SUB#4' Program)

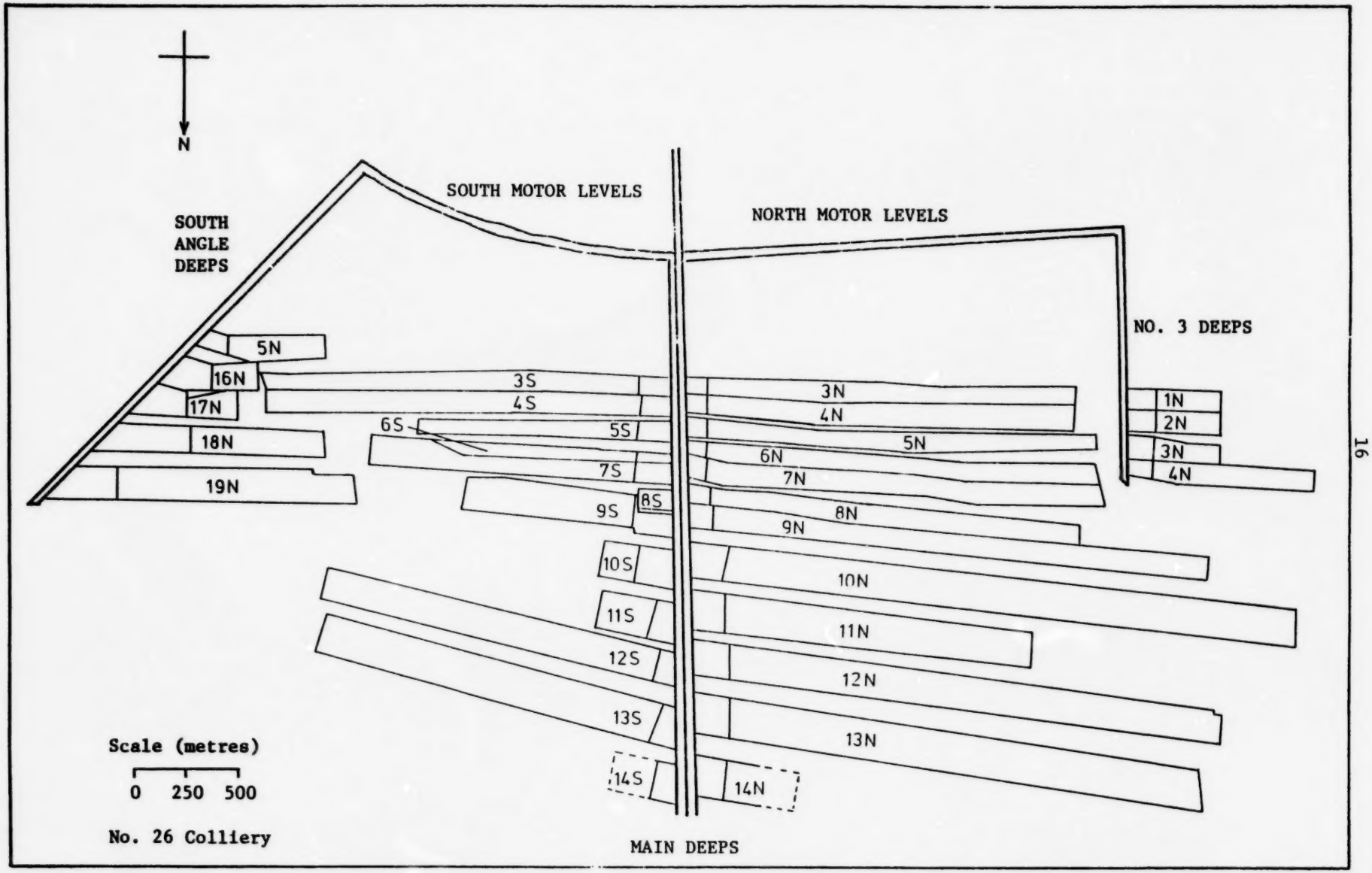

Figure 3 - No. 26 Colliery

Side), 1 to 4 North (No. 3 Deep) and 5 North, 16 to 19 North (South Angle Deep). Mining parameters for the individual panels are given in Tables 8 and 9, but can be summarized as follows:

	North Side	South Side	South Angle Deep	No. 3 Deep
Panel Width (m)	103-203	94-201	131-175	96-127
Mean Extracted Seam Height (m)	1.89-2.05	1.88-2.02	1.89-1.96	1.95-2.02
Depth of Working (m)	329-662	333-717	304-565	319-390
Panel Length (m)	1665-2690	945-2335	545-1315	575-905
Mean Seam Gradient (m)	3.7-7.1	2.8-6.0	2.1-4.4	4.5-5.3
Mean Pillar Width (m)	50-120	37-90	N/A	N/A

As the workings extended further offshore, the depth of cover between the Harbour Seam and seabed increased, with the seam gradient decreasing from about 1 in 4 in the region of the 3 North and 3 South faces to about 1 in 7 in the vicinity of the 13 North and 13 South faces.

SUBSIDENCE PARAMETERS

Examination of Figure 3 shows that many of the early No. 26 panels were worked adjacent to one another, which suggests that they were probably worked using the centre gate method. The predicted subsidence parameters for the mine can therefore be presented in two ways:

1) Treat each panel individually.
2) Treat panels worked adjacent one another as a single or composite panel.

Individual Panel Widths

Predicted maximum subsidence, compressive and tensile strain values along with the corrected tensile strain values for the mean seam gradient are given in Table 10.

Level (Panel)	Face Width (m)	Panel Length (m)	Extracted Seam Ht. (m)			Depth of Cover (m)		
			Max	Min	Mean	Max	Min	Mean
3 North	103.6	1932	2.08	1.73	2.01	338.2	317.6	329.2
4 North	109.7	1923	2.18	1.68	1.94	362.0	330.6	350.9
5 North	108.2	2071	2.03	1.78	1.89	396.0	363.4	380.5
6 North	108.2	2096	2.06	1.88	1.96	426.1	392.4	410.6
7 North	102.1	2105	2.08	1.96	2.01	452.2	412.3	433.0
8 North	100.6	1975	1.98	1.88	1.93	482.8	448.8	467.2
9 North	117.3	2681	2.06	1.83	1.96	509.3	464.5	485.4
10 North	190.5	3123	2.11	1.85	1.98	562.9	496.4	532.1
11 North	190.5	1663	2.01	1.88	1.96	609.6	575.0	593.4
12 North	172.2	2672	2.16	1.88	1.98	644.6	576.9	613.2
13 North	202.7	2689	2.11	1.96	2.05	693.6	629.5	662.7
1 North No. 3 Deeps	103.6	577	2.11	1.70	1.96	322.0	316.6	319.1
2 North No. 3 Deeps	126.5	780	2.08	1.70	1.95	342.9	337.3	340.8
3 North No. 3 Deeps	96.0	810	2.13	1.96	2.02	373.5	367.0	370.8
4 North No. 3 Deeps	109.7	902	2.13	1.96	2.01	391.6	388.8	390.3

Table 8 - Mining Parameters - No. 26 Colliery

Level (Panel)	Face Width (m)	Panel Length (m)	Extracted Seam Ht. (m)			Depth of Cover (m)		
			Max	Min	Mean	Max	Min	Mean
5 North South Angle	131.1	544	1.90	1.88	1.89	314.3	295.4	304.9
18 North South Angle	167.6	765	1.98	1.85	1.92	496.7	462.6	479.8
19 North South Angle	175.3	1314	2.03	1.90	1.96	586.1	550.0	565.7
3 South	94.5	2034	2.06	1.85	1.93	336.8	329.6	333.7
4 South	108.2	2034	2.01	1.83	1.92	377.1	367.7	373.4
5 South	105.1	1196	1.96	1.88	1.91	434.7	408.5	420.1
6 South	105.1	946	1.96	1.88	1.92	459.3	437.9	448.5
7 South	118.9	1452	1.98	1.88	1.92	489.4	464.4	477.6
9 South	187.5	952	1.93	1.83	1.88	532.9	524.3	528.0
12 South	172.2	1841	2.18	1.90	2.04	672.8	667.4	671.0
13 South	201.2	2333	2.16	1.90	2.02	719.1	714.9	717.2
				(1.4h > L)				
14 North	201.2	655	2.24	2.01	2.10	733.1	727.6	731.1
10 South	181.4	201	1.93	1.83	1.88	582.7	578.0	580.4
11 South	207.3	272	2.18	2.08	2.13	635.4	631.4	633.4
16 North South Angle	131.1	263	1.93	1.83	1.88	353.7	348.5	351.1
17 North South Angle	125.0	230	1.88	1.65	1.77	401.3	395.9	398.6

Table 8 Cont'd - Mining Parameters - No. 26 Colliery

Level (Panel)	Gradient Across Panel (1 in x)		
	Max	Min	Mean
3 North	3.9	4.2	3.9
4 North	4.1	5.2	4.4
5 North	3.0	4.3	3.7
6 North	3.5	6.5	4.4
7 North	3.6	4.3	4.0
8 North	3.2	5.3	4.3
9 North	4.3	5.2	4.7
10 North	4.3	6.8	5.5
11 North	5.3	6.0	5.6
12 North	5.7	7.1	6.2
13 North	6.6	7.7	7.1
1 North No. 3 Deeps	4.1	5.1	4.6
2 North No. 3 Deeps	4.9	5.5	5.1
3 North No. 3 Deeps	3.5	4.4	3.9
4 North No. 3 Deeps	4.8	6.1	5.3

Table 9 - Seam Gradient - No. 26 Colliery

Level (Panel)	Gradient Across Panel (1 in x)		
	Max	Min	Mean
5 North South Angle	4.1	4.7	4.4
18 North South Angle	1.7	2.7	2.1
19 North South Angle	1.7	4.4	3.0
3 South	2.4	3.4	2.8
4 South	2.4	3.5	2.8
5 South	2.1	3.6	2.9
6 South	3.3	3.8	3.6
7 South	1.9	4.7	3.8
9 South	3.6	4.1	3.9
12 South	4.5	8.7	5.8
13 South	5.1	6.5	5.9
	(1.4h > L)		
14 North	6.6	7.6	7.2
10 South	3.9	4.9	4.4
11 South	5.0	5.5	5.3
16 North South Angle	3.5	3.7	3.6
17 North South Angle	2.5	4.0	3.2

Table 9 Cont'd - Seam Gradient - No. 26 Colliery

Panel	Max Sub (m)	Max Strain (mm/m)		Gradient (1:x)	Corrected Tensile for Gradient (mm/m)	
		Tens	Comp		Rise	Dip
3 North	0.42	0.90	2.50	3.9	0.50	1.29
4 North	0.45	0.89	2.48	4.4	0.53	1.25
5 North	0.42	0.76	2.18	3.7	0.41	1.12
6 North	0.39	0.62	1.96	4.4	0.37	0.87
7 North	0.30	0.42	1.53	4.0	0.23	0.60
8 North	0.27	0.35	1.27	4.3	0.20	0.49
9 North	0.31	0.42	1.36	4.7	0.26	0.58
10 North	0.55	0.83	1.93	5.5	0.58	1.09
11 North	0.45	0.57	1.44	5.6	0.40	0.74
12 North	0.36	0.41	1.16	6.2	0.31	0.51
13 North	0.41	0.43	1.21	7.1	0.35	0.51
1 North No. 3 Deeps	0.43	1.01	2.57	4.6	0.61	1.42
2 North No. 3 Deeps	0.64	1.51	3.40	5.1	1.01	2.01
3 North No. 3 Deeps	0.38	0.67	2.17	3.9	0.38	0.97
4 North No. 3 Deeps	0.42	0.76	2.16	5.3	0.51	1.01

Table 10 - Subsidence Data - No. 26 Colliery (Modified 'SUB#4' Program)

Panel	Max Sub (m)	Max Strain (mm/m)		Gradient (1:x)	Corrected Tensile for Gradient (mm/m)	
		Tens	Comp		Rise	Dip
5 North South Angle	0.72	1.88	3.77	4.4	1.13	2.64
18 North South Angle	0.58	0.96	2.22	2.1	0.36	1.56
19 North South Angle	0.45	0.56	1.55	3.0	0.26	0.86
3 South	0.41	0.85	2.43	2.8	0.39	1.31
4 South	0.44	0.83	2.37	2.8	0.36	1.29
5 South	0.36	0.56	1.81	2.9	0.26	0.86
6 South	0.33	0.44	1.60	3.6	0.22	0.65
7 South	0.35	0.47	1.52	3.8	0.26	0.68
9 South	0.53	0.80	1.84	3.9	0.45	1.15
12 South	0.31	0.30	0.96	5.8	0.21	0.38
13 South	0.34	0.34	0.96	5.9	0.24	0.43
			1.4h > L			
14 North	0.34	0.37	0.95	7.2	0.30	0.44
10 South	0.13	0.18	0.44	4.4	0.11	0.25
11 South	0.21	0.26	0.63	5.3	0.17	0.34
16 North South Angle	0.48	1.09	2.46	3.6	0.55	1.62
17 North South Angle	0.27	0.54	1.32	3.2	0.26	0.81

Table 10 Cont'd - Subsidence Data - No. 26 Colliery (Modified 'SUB#4' Program)

Maximum subsidence and corrected tensile strain values for the four main areas of No. 26 Mine can be summarized as follows:

	North Side	South Side	South Angle Deep	No. 3 Deep
Maximum Vertical Subsidence (m)	0.27-0.45	0.31-0.53	0.45-0.72	0.38-0.64
Corrected Tensile Strain (Dipside) (mm/m)	0.44-1.29	0.25-1.31	0.81-2.64	0.97-2.01

Composite Panel Widths

Three mining areas in the No. 26 Mine workings were identifed where the pillar width between adjacent panels was very small, Figure 3: 3 to 9 North (North Side), 3 to 7 South (South Side) and 1 to 4 North (No. 3 Deeps). In these areas, the panels can either be treated individually or as composites (sum of the adjacent panel widths).

Mining parameters for a variety of composite panel configurations in the three areas identified are given in Tables 11 and 12. Predicted maximum subsidence, compressive and tensile strain values along with the corrected tensile strain values for the mean seam gradient are given in Table 13.

Maximum subsidence and corrected tensile strain values for the three composite areas can be summarized as follows:

	North Side	South Side	No. 3 Deep	South Angle Deep
Maximum Vertical Subsidence (m)	0.88-1.74	1.08-1.71	1.18-1.73	N/A
Corrected Tensile Strain (Dipside) (mm/m)	2.03-5.27	3.70-5.03	3.21-5.30	N/A

Level (Panel)	Face Width (m)	Panel Length (m)	Extracted Seam Ht. (m)			Depth of Cover (m)		
			Max	Min	Mean	Max	Min	Mean
3,4,5,6,7 North	568.1	1054	1.93	1.88	1.91	-	-	380.8
3,4,5 North	341.3	1950	2.13	1.73	1.95	-	-	353.5
6,7 North	225.5	2109	2.06	1.91	1.98	-	-	421.8
8,9 North	237.7	1975	1.96	1.93	1.95	-	-	476.3
1N, 2N No. 3 Deeps	234.0	570	2.11	1.70	1.96	-	-	329.9
3N, 4N No. 3 Deeps	237.7	808	2.01	1.93	1.97	-	-	380.5
1N,2N,3N,4N No. 3 Deeps	501.0	702	2.06	1.78	1.97	-	-	355.2
3,4 South	198.7	2042	2.08	1.91	1.96	-	-	353.5
3,4,5,6,7 South	560.8	1200	1.98	1.88	1.92	-	-	410.6
3S, 4S @ Face	198.7	838	1.98	1.91	1.93	-	-	353.5
3,4,5 South	329.8	1196	2.01	1.83	1.92	-	-	373.4

Table 11 - Mining Parameters - No. 26 Mine composite panels

Level (Panel)	Gradient Across Panel (1 in x)		
	Max	Min	Mean
3,4,5,6,7 North	4.0	4.3	4.1
3,4,5 North	3.9	4.4	4.2
6,7 North	4.0	6.0	4.7
8,9 North	3.6	5.8	4.7
1N, 2N No. 3 Deeps	4.8	10.4	6.8
3N, 4N No. 3 Deeps	4.7	7.0	5.6
1N,2N,3N,4N No. 3 Deeps	4.9	5.1	5.0
3,4 South	2.4	6.2	3.6
3,4,5,6,7 South	2.8	3.7	3.2
3S, 4S @ Face	2.5	3.4	2.9
3,4,5 South	2.1	3.7	2.9

Table 12 - Seam Gradient - No. 26 Mine composite panels

Panel	Max Sub (m)	Max Strain (mm/m)		Gradient (1:x)	Corrected Tensile for Gradient (mm/m)	
		Tens	Comp		Rise	Dip
3,4,5,6,7 North	1.74	3.66	2.28	4.1	2.05	5.27
3,4,5 North	1.58	3.57	2.68	4.2	2.07	5.08
6,7 North	0.99	1.88	2.82	4.7	1.16	2.59
8,9 North	0.88	1.47	2.58	4.7	0.91	2.03
1N, 2N No. 3 Deeps	1.33	3.23	3.23	6.8	2.52	3.94
3N, 4N No. 3 Deeps	1.18	2.48	2.95	5.6	1.76	3.21
1N,2N,3N,4N No. 3 Deeps	1.73	3.90	2.43	5.0	2.50	5.30
3,4 South	1.10	2.48	3.41	3.6	1.27	3.70
3,4,5,6,7 South	1.71	3.33	2.08	3.2	1.63	5.03
3S, 4S @ Face	1.08	2.45	3.36	2.9	1.12	3.77
3,4,5 South	1.46	3.13	2.34	2.9	1.44	4.82

Table 13 - Subsidence Data - No. 26 Mine composite panels
(Modified 'SUB#4' Program)

DISCUSSION

Two constraints exist regarding the mining of undersea mineral reserves: depth of cover and seabed strains. In the Sydney Coalfield, the amount of cover between seabed and the mining horizon is governed by the Canadian Labour Code - Coal Mines (CBDC) Safety Regulations (7), which state:

> Section 115 - No mine shall be worked below the sea bottom or below any other body of water except under the following conditions:
>
> a) No submarine seam of coal or stratified deposit shall be worked under less cover than 180 ft (55 m) of solid measure, except that an owner or lessee of any area may drive passageways to win the mineral to be worked and such passageways may have a cover less than 180 ft (55 m) but not less than 100 ft (30.5 m) of solid measure.

The current maximum allowable tensile strain at seabed, in the Sydney Coalfield, is 8.5 mm/m. This value was recommended in a report submitted by K. Wardell and Partners (8) to the 1974 Commission of Inquiry into undersea mining in Cape Breton. The derivation and applicability of this value to the Sydney Coalfield is fully discussed elsewhere (6).

At each of the three mines examined, Prince, Lingan and No. 26, the longwall panels have all been worked at depths exceeding the 55 m limit imposed by the Canadian Labour Code. In addition, the predicted seafloor tensile strains (using the NCB SEH) have all remained below the 8.5 mm/m value recommended by K. Wardell and Partners. At Prince Mine, the greatest predicted seafloor tensile strain was 4.87 mm/m over the 4 East panel. At Lingan Mine and No. 26 Mine, the greatest predicted seafloor tensile strains (corrected for seam gradient) were 5.00 mm/m and 2.64 mm/m over the 1 East and 5 North panel (South Angle Deep) respectively.

In the case of the No. 26 Mine composite panels, predicted seafloor tensile strains (corrected for seam gradient) of up to 5.30 mm/m were calculated over the combined 1 to 4 North panels (No. 3 Deeps). The calculated composite panel tensile strains remained well within the 8.5 mm/m guideline used in the Sydney Coalfield.

Table 14 lists the longwall faces at Lingan (1 panel) and No. 26 (11 panels - individual and composite) which were affected by altering the 'k' factor to 0.80. At Lingan, only the 1 East panel was affected, with the maximum predicted tensile strain on the dipside increasing from 4.37 to 5.00 mm/m (14%). At No. 26 (individual panels) the 14N, 10S, 11S and 7N South Angle panels were affected with predicted dipside tensile strains increasing from 3% (11S) to 22% (14N). Seven No. 26 composite panels were affected, with the predicted dipside tensile strains increasing from 6% to 23%, Table 14.

At Prince Mine, alteration of the 'k' factor resulted in no changes to the predicted maximum tensile strain values for any of the panels examined.

It is generally recognised that the NCB SEH cannot be used to accurately predict subsidence profiles in the U.S. Appalachian and mid-West Coalfields. However, it should be noted that although the Sydney Coalfield appears to be a northern extension of the Appalachian Coalfield, it also bears marked geological/structural similarities to the British Coalfields. It is therefore concluded, that given the wide range of conditions under which the NCB SEH data was collected, the SEH can be applied to the Sydney Coalfield providing it is realised that the error may be greater than the ±10% normally quoted (6).

CONCLUSION

A back analysis of subsidence profiles for the Prince, Lingan and No. 26 Mine workings, using the 'modified' NCB SEH method, reveals that all the longwall panels (to date) have resulted in predicted seafloor tensile strains below the 8.5 mm/m guideline value currently used in the Sydney Coalfield. At Prince Mine, 4.87 mm/m was predicted over the 4 East panel, while at Lingan Mine, 5.00 mm/m was predicted over the 1 East panel. At No. 26 Colliery, 2.64 mm/m was predicted over the 5 North panel (South Angle Deeps), while 5.30 mm/m was predicted over the composite 1 to 4 North panels (No. 3 Deeps).

Finally, because of the uncertainty regarding the application of both the 'normal and modified' NCB SEH to the Sydney Coalfield, it is

	Maximum Tensile Strain			Tensile Strain Corrected for Gradient					
	NCB 'k'	Modified 'k'	Increase (%)	NCB 'k' Rise	NCB 'k' Dip	Modified 'k' Rise	Modified 'k' Dip	% Increase Rise	% Increase Dip
LINGAN									
1 East	3.22	3.67	14%	2.06	4.37	2.35	5.00	14%	14%
NO. 26 (Individual Panels)									
14N	0.30	0.37	23%	0.24	0.36	0.30	0.44	25%	22%
10S	0.16	0.18	12%	0.09	0.22	0.11	0.25	22%	13%
11S	0.25	0.26	4%	0.17	0.33	0.17	0.34	0%	3%
7N South Angle	0.47	0.54	15%	0.21	0.72	0.26	0.81	24%	12%
NO. 26 (Composite Panels)									
3,4,5,6,7 North	2.97	3.66	23%	1.66	4.28	2.05	5.27	23%	23%
3,4,5 North	2.90	3.57	23%	1.68	4.12	2.07	5.08	23%	23%
1N,2N No. 3 Deep	2.83	3.23	14%	2.21	3.45	2.52	3.94	14%	14%
3N,4N No. 3 Deep	2.33	2.48	6%	1.65	3.01	1.76	3.21	6%	6%
1N,2N,3N,4N No. 3 Deep	3.17	3.90	23%	2.03	4.31	2.50	5.30	23%	23%
3,4,5,6,7 South	2.71	3.33	23%	1.30	4.09	1.63	5.03	25%	23%
3,4,5 South	2.54	3.13	23%	1.17	3.91	1.44	4.82	23%	23%

Table 14 - Lingan and No. 26 panels affected by altering the 'k' factor to 0.80

recommended that the results obtained by this method be used with caution and assumed to be a 'good first order approximation' of the actual profiles developing.

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